THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

WOOD AND PULPING CHARACTERISTICS OF EIGHT-YEAR-OLD HYBRID LARCH

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SUMMARY

Eight-year-old hybrid larch chips were cooked to kappa number 50 and compared with 100% jack pine and 75% jack pine/25% larch mixture cooked to similar kappa numbers. A 75% jack pine/25% larch mixture was also cooked to kappa number 30 and the bleached and unbleached pulp compared with 100% jack pine bleached pulp and a 50% jack pine/hybrid larch + 50% bleached hardwood pulp.

Results indicate that the eight-year-old hybrid larch chips, which contained about 23% bark, produced a pulp yield that was approximately 11% lower than the bark-free jack pine chips. Larch pulps had similar fiber length and fiber width and lower coarseness than the jack pine control pulps. The pulps produced from the hybrid larch whole-tree chips had strength properties that were significantly lower than those of the jack pine control pulps. However, mixing the larch chips with jack pine chips resulted in much improved pulp yields and produced pulps with strength properties that were only slightly lower than the jack pine control pulp.

INTRODUCTION

Eight 8-year-old hybrid larch trees were received from the U.S. Forest Service, Forestry Sciences Laboratory at Rhinelander in October of 1979. The eight trees were part of a short-rotation, intensive forestry study. The research plan was to characterize the trees and the chip samples derived from these trees and then pulp representative samples using a kraft pulping procedure. The chips were to be cooked to a kappa number 50 and the pulps evaluated using TAPPI standard handsheet testing procedures.

To make the results more meaningful, conventional debarked jack pine chips (age 55 - control) were pulped using similar procedures. In addition, a 25% 8-year-old hybrid larch/75% jack pine chip mixture cook was made for comparison with the 8-year-old, whole-tree pulp and the jack pine control pulp.

It was agreed in advance that the U.S.F.S. would characterize the trees as to size, fiber length, percent bark, and specific gravity. In addition to providing the handsheet strength data, the Institute was to provide estimates of the percent latewood (from pulps), percent heartwood (from disks) and percent compressionwood (from disks). It was also agreed that the Institute would provide information on alcohol-benzene extractives, hot-water extractives, chip size, percent bark in the chips being pulped, and fiber length, fiber width, cell wall thickness and fiber coarseness for both the kappa number 30 and kappa number 50 pulps.

WOOD AND TREE QUALITY INFORMATION

Two disks were taken at 6-foot intervals from each tree, begining at the 0.5-foot level up to approximately a one-inch top. An additional two disks were taken at d.b.h. (4.5-foot level). These disks were used to obtain percent heartwood, percent compressionwood, and percent alcohol-benzene and hot-water extractives.

Percent heartwood was obtained by placing the disks on a light box, marking the heartwood and then calculating the percent heartwood by dividing the area occupied by the heartwood by the area of the total disk. Percent compressionwood was calculated by counting the number of dots in the grid that fell in the compressionwood areas and dividing that number by the number of dots on the whole disk. The values obtained for each disk were weighted on a volume basis and used to obtain a weighted average percent heartwood and compressionwood for the entire tree. Given in Table I is information on tree size and the weighted values for percent heartwood and compressionwood. Also given for comparison purposes are the values obtained for jack pine.

The samples for alcohol-benzene and hot-water extractives determinations were obtained by removing the bark from the disks, halving them and compositing all disks for each tree (exluding the d.b.h. disks). Alcohol-benzene and hot-water extractives were determined by the Institute's Analytical Chemistry Department using TAPPI Standards T204 os-76 and T207 os-75 respectively. Extractives were determined separately and <u>not</u> consecutively. Given in Table II are the alcohol-benzene and hot-water extractives values obtained for both the hybrid larch and the jack pine control. Jack pine values were obtained from as composited chip sample.

TABLE I

TREE SIZE AND PERCENT HEARTWOOD AND COMPRESSIONWOOD

Tree No.	Height, m	Diameter, cm	Weighted Percent Heartwood	Weighted Percent Compressionwood
1	6.35	5.3	9.8	13.6
2	7.58	8.5	9.9	8.5
3	5.44	3.7	4.0	31.5
4	6.71	6.1	11.7	10.0
5	6.98	7.0	14.0	6.4
6	5.41	3.5	28.7	13.1
7	6.35	4.0	13.4	1.7
8	6.96	4.9	27.6	12.2
Jack Pine Control	-	-	28.7	7.5

After the disks were taken, the needles were removed and the rest of the tree, including bark, was chipped using a 3/4-inch chipper setting. Twigs, small branches, and small parts of the upper stem were bundled so they would feed in and chip properly. Chips from all trees were composited and mixed thoroughly. The composited mixture was then screened on Sweco screens using the 1-inch, 0.5-inch, and 0.25-inch screens. Oversized material (remaining on the 1-inch screen) was rechipped. Weights were taken on the following: (1) material rejected after rechipping (oversized), (2) material passing through the 0.25-inch screen (fines), (3) material on the 0.50-inch screen, and (4) material on the 0.25-inch screen. Oversized chips and fines were discarded and representative samples taken from the "on 0.5" and "on 0.25" chips for percent bark determinations. The chips were dried for 5-6 days and then stored in a freezer until used.

Total oven-dry weight of the chips was 79.6 lbs. Of this, 71.1 lbs were accepted chips (89.3%). Fines amounted to 7.3% and oversized material was 3.5%. The chips on the 0.5-inch screen amounted to 72.7% of the accepted chips while those on the 0.25-inch screen totalled 27.3%. Percent bark in the "on 0.5-inch" sample was 19.3% while that in the "on 0.25-inch" sample was 33.8%. Average percent bark in the composited chip sample amounted to 23%

The jack pine control bolts (8 bolts-Thilmany wood yard) were debarked and chipped, also with the 3/4-inch chip setting. Of the accepted chips, 86% were on the 0.5-inch screen and 14% were on the 0.25-inch screen.

PULP FIBER DIMENSIONS

Percent earlywood/latewood, fiber length, width and coarseness and cell wall thickness were all determined on representative pulp samples. Percent earlywood/latewood was determined by counting the total number of earlywood fibers and dividing by the total number of fibers of both types counted on five passes across each end of a slide. Pulp fiber length was determined by measuring 600+ fibers 0.3 mm and longer, including those cut, broken and intact. Fiber width and cell wall thickness were determined by measuring 100 fibers on approximately five passes across each end of a slide. Measured was the widest portion of each fiber, excluding those areas where swelling or other damage had occurred. Coarseness was measured according to Britt's method [Tappi 49(5):202-6(1966)] and expressed as mg/100 m. Table III gives the results obtained for percent earlywood and pulp fiber length, width, coarseness, and cell wall thickness.

TABLE II

ALCOHOL-BENZENE AND HOT-WATER EXTRACTIVES
WOOD ONLY SAMPLES

Tree No.	Alcohol-Benzene Extractives, %	Hot-Water Extractives, %
1	2.43	6.72
2	2.01	6.94
3	_[a]	_[a]
4	2.50	6.67
5	2.31	6.91
6	-	-
7	-	-
8	2.75	9.69
Jack Pine Control	3.54	2.31

[a] Insufficient sample for analysis.

TABLE III

PULP FIBER DIMENSIONS

	100% Larch 50 kappa	75% Jack Pine/ 25% Larch 30 kappa	75% Jack Pine/ 25% Larch 50 kappa	100% Jack Pine 50 kappa
Earlywood, %	62.8	58.1	59.2	61.7
Latewood, %	37.2	41.9	40.8	38.3
Fiber Length, mm				
Arithmetic Average	1.56	1.72	1.65	1.88
Weighted Average	2.12	2.23	2.16	2.22
Fiber Width, μm	40.6	42.3	39.9	42.1
Coarseness, mg/100 m	18.0	19.1	21.3	22.0
Cell Wall Thickness, μm	4.60	4.57	5.46	4.52

PULPING PROCEDURES

Chips were prepared from the eight trees according to the procedure given under "Wood and Tree Quality Information." The "on 0.5-inch" and "on 0.25-inch" fractions were composited and pulped. The composited sample contained 23% bark.

Pulping runs were carried out in a stainless steel vessel of about 72 liters capacity, fitted for external circulation and indirect heating. The chips were charged to a stainless steel basket, which closely matched the interior contours of the digester and which could be removed with the contents following the cook. The cooking liquors were prepared from solutions of sodium hydroxide and sodium sulfide of known concentration and density, together with the appropriate amount of dilution water. The pulping conditions are given in Table IV, together with yield data.

At the end of the cook, the digester pressure was slowly relieved to about 80 psi and the blow valve was subsequently opened to expel the spent liquor through a cyclone separator into a muslin-covered wash box where any entrained fibers were collected. The cover was removed, the blow valve closed, and a cold water line was attached to the liquor circulation system. The digester was then filled with water to within 6 inches of overflowing and the liquor circulating pump was operated for 5 minutes, following which the wash water was drained. The cooked chips were then fiberized at about 2% consistency under a Williams disintegrator fitted with a TAPPI disc.

The pulp was screened through a 0.006-inch cut screen plate in a small Valley flat screen. The rejects were oven dried, weighed, and discarded. The accepted fiber was partially thickened on a muslin-covered wash box, then transferred to a bag made of finely woven nylon cloth, where more water was removed by

centrifugation. The pulp cake was broken up mechanically and the wet crumbs were packed in polyethylene bags for storage. Representative samples taken at this time were weighed, oven-dried, and reweighed. The latter were used to calculate the yield of screened pulp.

Bleaching procedures employed a CEDED bleaching sequence. Bleaching conditions are described in Table V.

The physical properties of the pulps were determined according to TAPPI Standard Methods after beating in a PFI mill at 10% consistency.

TABLE IV

COOKING CONDITIONS AND YIELD DATA

Chip Composition	H-Factor	Kappa No.	Screened Yield % o.d. Wood	Screen Rejects %o.d. Wood
100% Jack Pine	1450	49.2	46.2	0.9
100% Jack Pine	1850	34.4	43.4	0.6
100% Hybrid Larch	1800	54.8	35.3	1.0
75% Jack Pine/ 25% Hybrid Larch	1900	34.2	44.8	1.5
75% Jack Pine/ 25% Hybrid Larch	1600	51.6	46.3	2.1

Constant Conditions:

Wood Charge, kg/ o.d.	4.0
Water-to-Wood Ratio, cc/g	4.0
Effective Alkali, % o.d. wood	16.0
Sulfidity, %	25
Time to 172°C, min	90

TABLE V

BLEACHING CONDITIONS

Bleaching Conditions	Sample E[a]	Sample G[a]
Chlorination Stage		
Pulp, g o.d.	500	500
Consistency, %	3.0	3.0
Temperature, °C	Ambient	Ambient
Time, min	45	45
Chlorine charge, % on o.d. pulp	8.34	8.3
Chlorine residual, % on o.d. pulp	Trace	1.03
Chlorine consumed, %	8.34	7.31
Extraction Stage		
Pulp, g o.d.	500	500
Consistency, %	10	10
Temperature, °C	60	60
Time, min	70	70
NaOH, % on o.d. pulp	4.7	4.7
End pH	12.4	12.3
Permanganate No. (25 mL)	5.9	5.2
Chlorine Dioxide Stage		
Pulp, g o.d.	495	495
Consistency, %	10	10
Temperature, °C	60	60
Time, min	180	180
Chlorine dioxide charge, % on o.d. pulp	1.5	1.5
Chlorine dioxide residual, % on o.d. pulp	0.12	0.32
Chlorine dixoide consumed, %	1.38	1.19
Extraction Stage		
Pulp, g o.d.	495	495
Consistency, %	10	10
Temperature, °C	60	60
Time, min	60	60
NaOH, % on o.d. pulp	1.0	1.0
End pH	12.3	10.5
Chlorine Dioxide Stage		
Pulp, g o.d.	495	495
Consistency, %	10	10
Temperature, °C	60	60
Time, min	180	180
Chlorine dioxide charge, % on o.d. pulp	0.5	0.5
Chlorine dioxide residual, % on o.d. pulp	0.34	0.16
Chlorine dioxide consumed, %	0.16	0.34

[a]Sample E is fully bleached 75% jack pine/25% hybrid larch. Sample G is 100% bleached jack pine.

PULPING RESULTS AND DISCUSSION

Pulp yield and cooking conditions are summarized in Table IV and the physical properties of the pulps, including a fully bleached kappa number 30 75% jack pine/25% hybrid larch pulp and a bleached conifer/hardwood pulp, are summarized in Tables VI and VII. Table VIII provides additional data on the bleached pulps, including brightness, opacity, smoothness, scattering coefficient, and transmittance.

The screened pulp yield of the 8-year-old kappa number 50 larch was lower than the jack pine control by about 11% and is apparently due to the juvenile nature of the wood and the high levels of twigs and bark in the chips pulped. The 75% jack pine/25% 8-year-old larch mixture had a kappa number 50 pulp yield that was about the same as that of the jack pine control (46.3% vs. 46.2%). Cooking the jack pine/larch mixture to a kappa number 30 resulted in a very modest drop in yield from 46.3% to 44.8%. A kappa number 30 100% 8-year-old hybrid larch pulp was not prepared. More severe cooking conditions were required for the juvenile larch in order to produce kappa number 50 pulps than was the case for the 100% jack pine.

The physical properties and beating behavior of the pulps are included in Tables VI and VII and are also compared in Fig. 1-4. Figure 1 is a plot of tear factor vs. breaking length and illustrates that the 100% 8-year-old hybrid larch is considerably weaker than the jack pine control pulps. This figure also demonstrates that the addition of 75% jack pine with 25% larch gives strength properties that are only modestly lower (4-6% less) than the jack pine control pulp. At a breaking length of 10 km, for example, tear factor is approximately 4% lower for the jack pine mixture than the pure jack pine pulp (Fig. 1).

TABLE VI

UNBLEACHED PULP PHYSICAL PROPERTIES

Chip Mixture	Kappa No.	No. of Revs.	CSF, mL	Density, g/cc	Burst Factor	Tear Factor	Breaking Length, km	Zero-Span Breaking Length, km	Tea, $kg \cdot m/m^2$	Stretch, %
100% Jack pine	50	0	725	0.528	46.2	182	6.33	19.8	5.0	2.0
		1000	705	0.629	65.4	153	8.31	20.2	9.5	2.8
		5000	510	0.717	87.0	122	10.82	20.9	14.6	3.4
		6000	455	0.720	88.8	114	11.10	19.8	14.9	3.4
		7500	345	0.744	95.2	111	11.15	20.0	15.6	3.5
		9000	260	0.754	89.5	108	11.28	21.3	15.3	3.4
75% Jack pine/25% hybrid larch	51.6	0	740	0.528	40.6	165	6.51	18.4	6.4	2.3
		1000	700	0.614	63.1	153	8.16	19.6	10.4	3.2
		5000	570	0.694	82.6	115	10.35	18.0	14.6	3.6
		6500	510	0.710	80.4	116	10.38	19.3	16.3	3.8
		7500	480	0.712	83.4	114	11.13	19.0	17.2	3.9
		9000	380	0.712	85.6	113	10.69	18.8	15.9	3.6
100% Hybrid larch	54.8	0	710	0.544	38.1	113	6.40	13.9	6.2	2.3
		1000	580	0.610	57.0	110	8.07	15.4	11.6	3.3
		5000	430	0.643	64.8	99	8.59	15.9	12.7	3.5
		6500	410	0.661	63.5	97	9.03	15.6	14.1	3.7
		7500	365	0.680	64.2	92	9.19	16.0	14.4	3.7
		9000	330	0.687	66.2	99	8.94	15.6	13.9	3.7

TABLE VII

BLEACHED PULP PHYSICAL PROPERTIES

Chip Mixture	Kappa No.	No. of Revs.	CSF, mL	Density, g/cc	Burst Factor	Tear Factor	Breaking Length, km	Zero-Span Breaking Length, km	Tea, $kg \cdot m/m^2$	Stretch, %
100% Jack pine	34.4	0	730	0.612	29.0	269	4.60	17.0	6.7	3.2
		2000	640	0.709	84.9	136	10.24	19.6	17.8	4.4
		5500	455	0.736	94.1	118	11.46	20.3	19.8	4.4
		8000	345	0.756	95.2	124	11.65	21.8	19.9	4.4
		9500	285	0.759	93.1	113	11.55	20.9	19.3	4.2
75% Jack pine/25% hybrid larch[a]	34.2	0	730	0.522	43.0	182	6.12	17.8	6.2	2.3
		1000	680	0.629	65.1	162	8.20	18.8	12.1	3.4
		5000	510	0.707	83.2	125	10.45	19.3	15.6	3.7
		6500	460	0.722	81.9	115	10.53	18.3	15.6	3.8
		7500	410	0.708	88.8	122	10.92	18.8	16.0	3.7
		9000	310	0.741	88.8	98	11.01	19.3	17.0	3.9
75% Jack pine/25% hybrid larch fully bleached	34.2	0	730	0.636	42.3	224	5.89	17.1	8.9	3.4
		500	670	0.700	73.4	154	9.13	18.3	15.3	4.1
		1500	590	0.737	87.1	132	10.36	19.3	17.2	4.2
		3500	470	0.763	91.2	113	11.35	19.7	18.3	4.2
		5000	400	0.776	96.8	106	11.88	19.1	19.4	4.3
50% Jack pine/ hybrid larch mixture + 50% bleached hardwood	-	0	720	0.574	24.2	191	3.81	14.9	4.7	2.6
		500	640	0.635	40.1	143	6.25	16.8	8.9	3.3
		1500	590	0.685	56.1	124	7.75	17.8	11.2	3.6
		3000	490	0.722	65.9	111	9.11	18.1	15.4	4.1
		4500	380	0.742	71.9	102	9.36	18.8	14.7	3.9

[a] This chip mixture was unbleached.

TABLE VIII

ADDITIONAL HANDSHEET PROPERTIES BLEACHED PULPS

Chip Mixture	Kappa No.	No. of Revs.	Brightness % GE	Tappi Opacity	Smoothness		Scattering Coefficient	Transmittance
					Wire	Felt		
100% Jack pine	34.4	0	90.3	72.0	278	978	87.1	35.6
		2000		59.6	245	1271	85.4	46.2
		5500		55.3	208	1180	84.3	50.5
		8000		53.1	181	1525	83.8	52.3
		9500		52.6	121	1292	83.3	52.5
75% Jack pine/25% hybrid larch	34.2	0	88.0	70.6	223	916	88.0	36.0
		500		65.5	143	1116	87.1	40.7
		1500		59.5	104	1113	86.1	46.3
		3500		54.5	68	1407	84.5	50.7
		5000		52.7	141	1335	84.8	52.3
50% Jack pine/ hybrid larch mixture + 50% bleached hardwood	-	0	86.0	78.0	273	880	89.2	30.2
		500		73.4	192	776	89.0	34.7
		1500		68.3	137	812	88.0	38.2
		3000		66.2	105	947	87.3	41.0
		4500		62.2	98	904	86.6	43.2

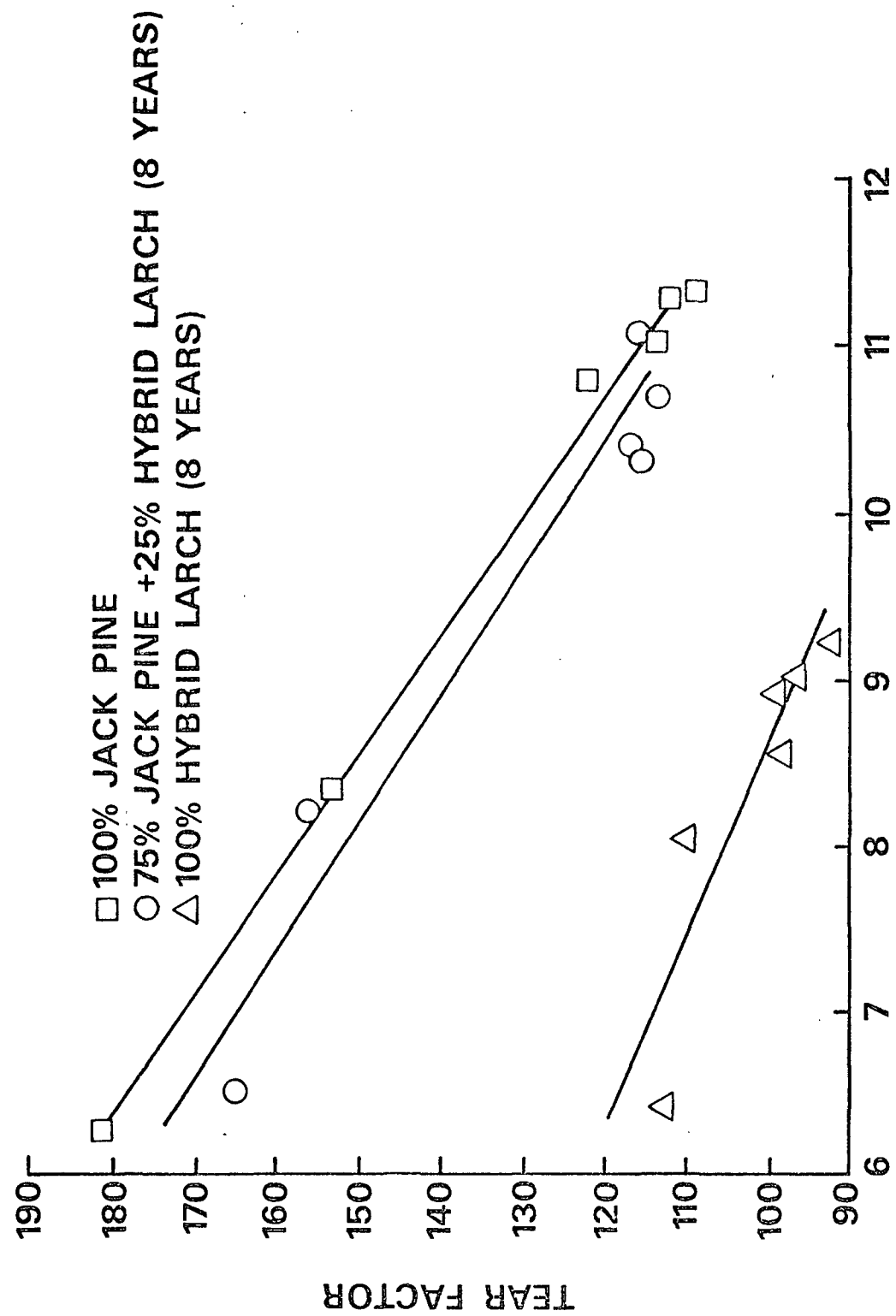

Fig.1 Tear factor vs breaking length at 50 kappa

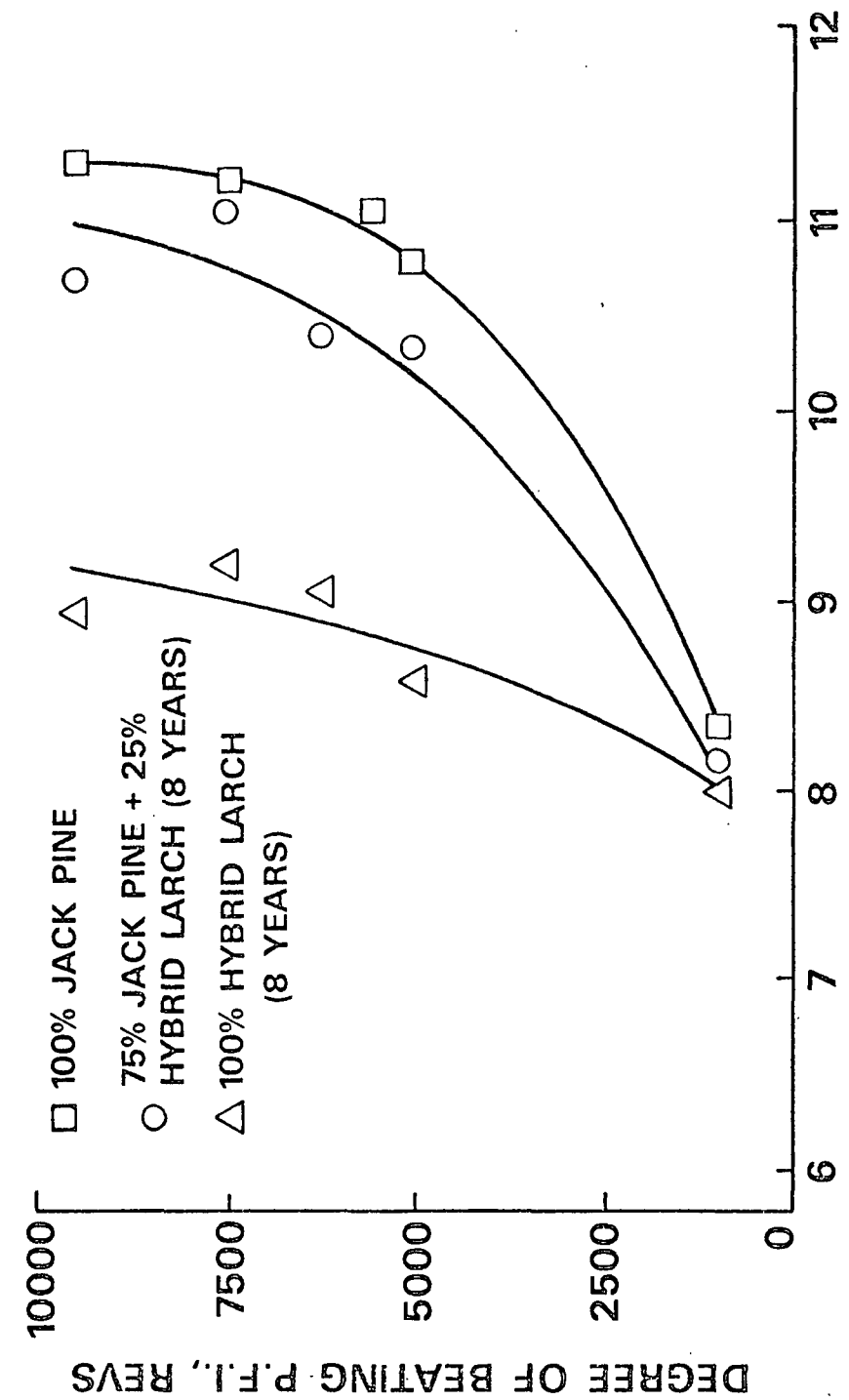

Fig.2 Degree of beating vs breaking length at 50 kappa

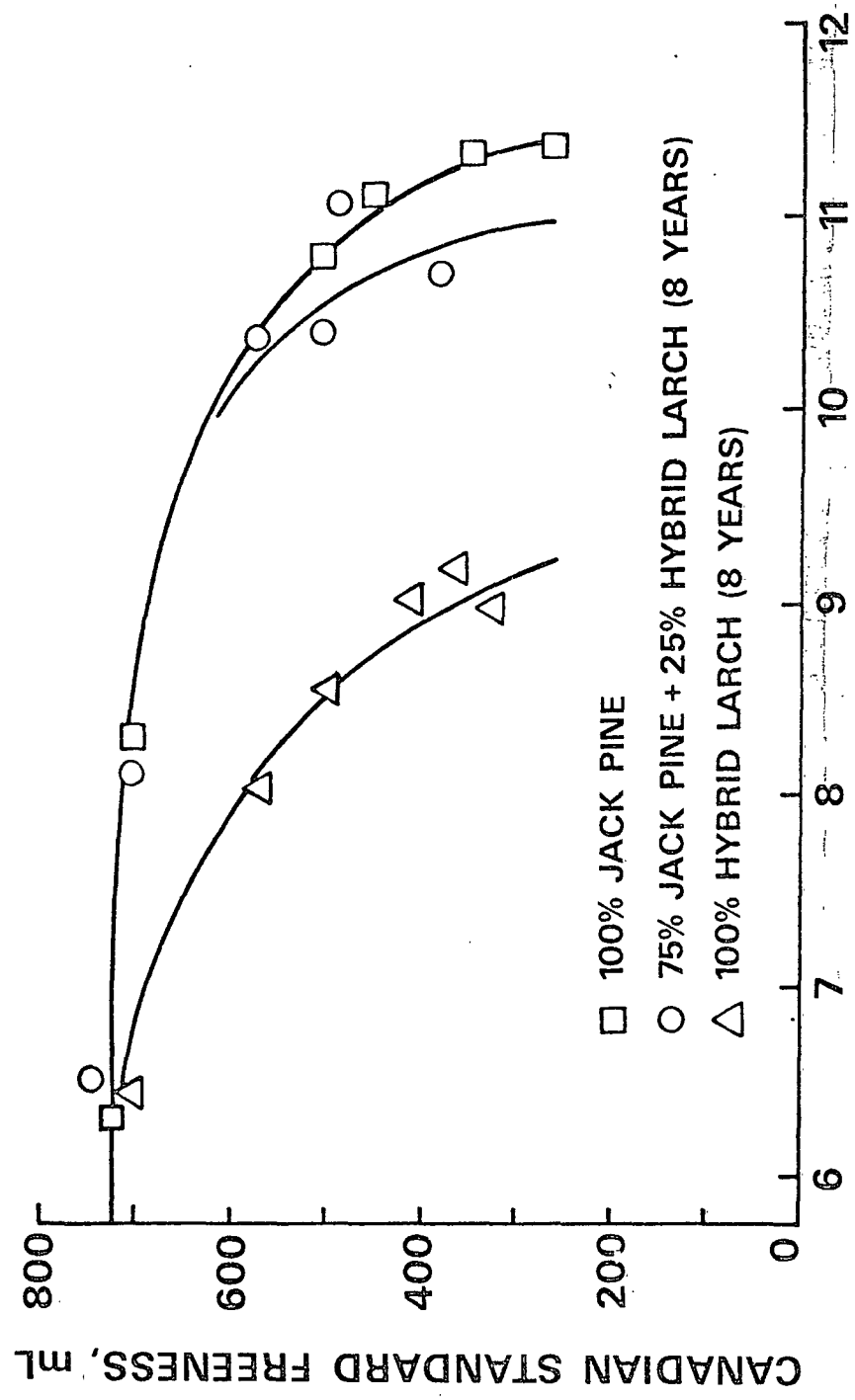

Fig.3 Freeness vs breaking length at 50 kappa

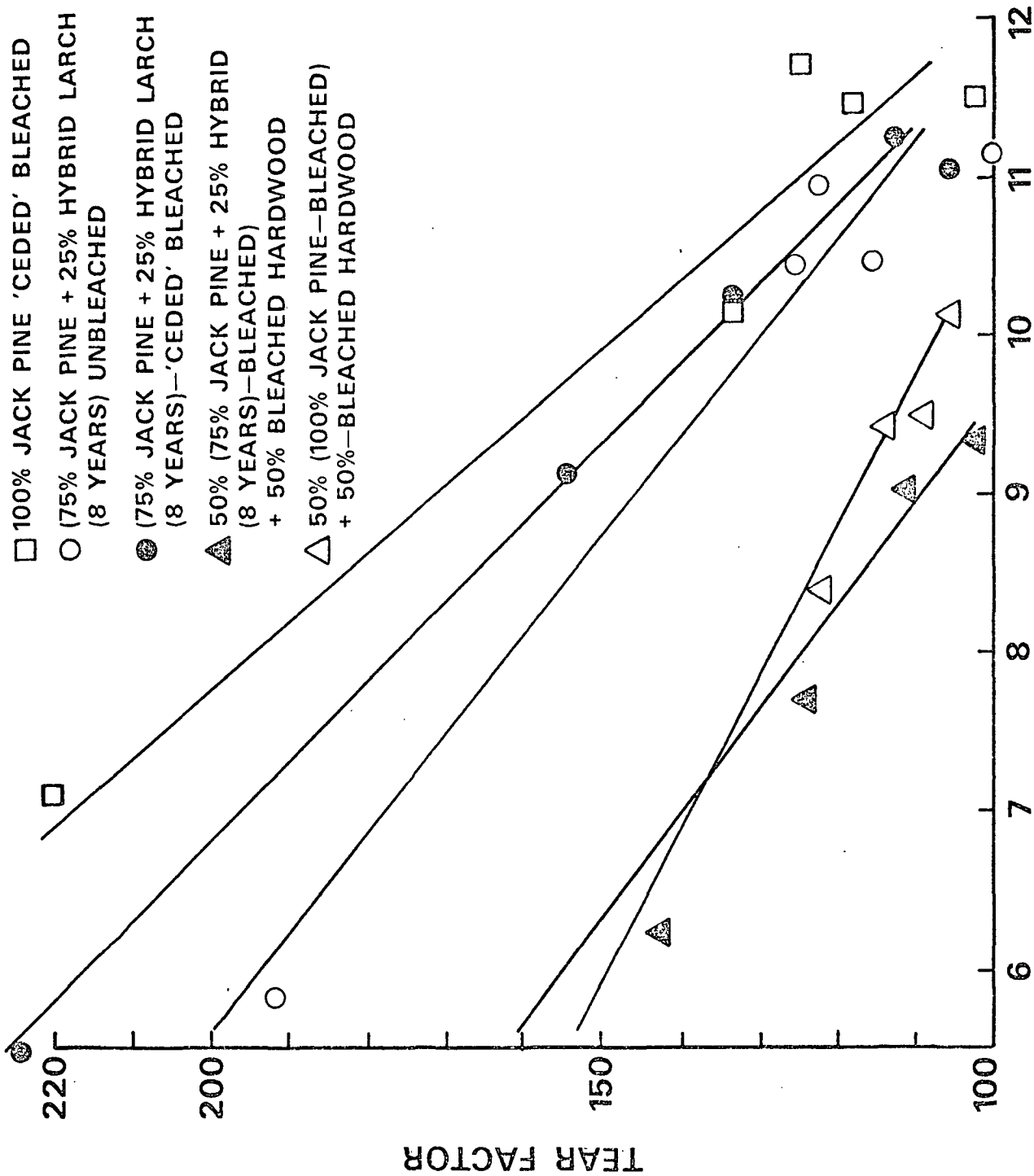

Fig. 4 Tear factor vs breaking length for bleached pulps

The normal procedure for developing burst strength and breaking length is to beat the pulps. When this is done, burst strengthand breaking length values normally increase and tearing strength decreases. This type of trend is illustrated in Fig. 1, where tear factor was plotted over breaking length. Figure 2 illustrates that, when the three types of pulps were beaten, the 8-year-old larch behaved differently than the 100% jack pine and the jack pine/larch mixture. The 8-year-old larch improved only a small amount in breaking length with beating and, at all beating levels, had a substantially lower breaking length than either the jack pine/larch mixture or the 100% jack pine pulps.

When breaking length of the three pulps are compared at several freeness levels (Fig. 3), the results are as anticipated. The 8-year-old larch pulps, when beaten to improve burst strength and breaking length, produce pulps that have lower (9 vs. 11 km) breaking strength at freeness levels of 200-600 than the pulps containing jack pine. The 8-year-old larch pulp also had lower zero-span tensile strength (inherent fiber strength) and lower bursting strength than the pulps containing jack pine. Using juvenile larch in a mixture with other conifers, as may well happen in practice, produces satisfactory pulp strength.

The usefulness of 8-year-old larch as a bleached pulp was investigated by cooking the 75% jack pine/25% larch chips to a kappa number of 34 and bleaching (CEDED) to an 88 brightness. The strength values were compared on both bleached and unbleached pulps. The jack pine/larch mixture was more difficult to bleach than the jack pine, as indicated by the relatively larger amounts of ClO required to obtain an 88 brightness for the jack pine/larch mixture (Table V). Higher levels of hot-water extractives and the 23% bark in the larch fraction are believed to be the reasons for bleaching response.

The strength properties of bleached pulps are compared n Fig. 4. The strength properties of the bleached jack pine/8-year-old larch mixture were higher than comparable unbleached pulps. The improved strength was believed to be due to the lignin removal which occurs as a result of bleaching. The pulp that was a 50/50 mixture of bleached hardwood and the bleached 75% jack pine/25% hybrid larch, although not as strong as the other pulps in this study, produced a pulp that appears equal to or superior to most hardwood pulps.

CONCLUSIONS

1. Wood samples of the 8-year-old larch had lower levels of alcohol-benzene extractives and higher levels of hot-water extractives than the jack pine strength properties that were only modestly lower than those of the jack pine control pulp.

2. Eight-year-old hybrid larch chips, which contained about 23% bark, produced a pulp yield that was approximately 11% lower than the bark-free jack pine chips.

3. Pulps of the 8-year-old hybrid larch had fiber length and fiber width similar to those of jack pine control pulps and lower coarseness than the jack pine control pulps.

4. The pulps produced from the 8-year-old hybrid larch whole-tree chips had strength properties (tear strength, burst strength, breaking length, and zero-span tensile strength) that were significantly lower than those of the jack pine control pulps.

5. Mixing the 8-year-old larch chips with jack pine chips (75% jack pine/25% larch) resulted in much improved pulp yields and produced pulps with strength properties that were only modestly lower than those of the jack pine control pulp.

6. Bleached kappa number 34 pulps were produced from the 75% jack pine/25% larch chip mixtures that had improved strength properties over those of comparable unbleached pulps.

7. Pulps with satisfactory strength characteristics resulted when the bleached 75% jack pine/25% larch pulps were mixed with bleached hardwood pulp on a 50/50 basis.

8. Pulps from the 75% jack pine/25% larch chip mixture were more difficult to bleach than the jack pine control pulp.

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